



Anaerobic Digestion – the Basics

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What is Anaerobic Digestion?

- **Anaerobic digestion occurs when organic material decomposes biologically in the absence of oxygen**



Benefits of Anaerobic Digestion

- **Odor reduction (digestion stabilizes degradable organic matter)**
- **Digested manure retains most of its nutrient/fertilizer value**
- **Digestion minimizes release of methane to atmosphere during later storage**

History of Biogas

- 10th century BC - Used to heat water in Assyria
- 16th century – Used to heat water in Persia
- 17th century - Flammable gases found to be emitted from decaying organic matter
- 1776 - Relationship between the amount of decaying organic matter and the amount of flammable gas produced demonstrated

History, cont.

- 1808 - Methane produced via controlled anaerobic digestion of cattle manure
- 1859 - First digestion plant built in India
- 1895 - Biogas recovered from a sewage treatment plant in England lit street lamps
- 1930s - Developments in microbiology identified the anaerobic bacteria and conditions needed to promote methane production

History, cont.

- 1970s - Energy crisis renewed interest in AD
- 1970s - 80s - Lack of understanding and overconfidence resulted in numerous failures
 - China, India and Thailand reported 50% failure rates
 - Failures of farm digesters in U.S. approached 80%



Reasons for Failures

- **Benefits oversold - unrealistic expectations**
- **Operations too small to justify digester**
- **High operating costs**
- **Unreliable market for biogas**
- **Management failures**



What's Different Now:

- **Improved designs**
- **Better understanding of O&M requirements**
- **Higher prices for liquid fuel & natural gas**
- **Market evolving for “carbon credits” as well as biogas energy**

Currently -

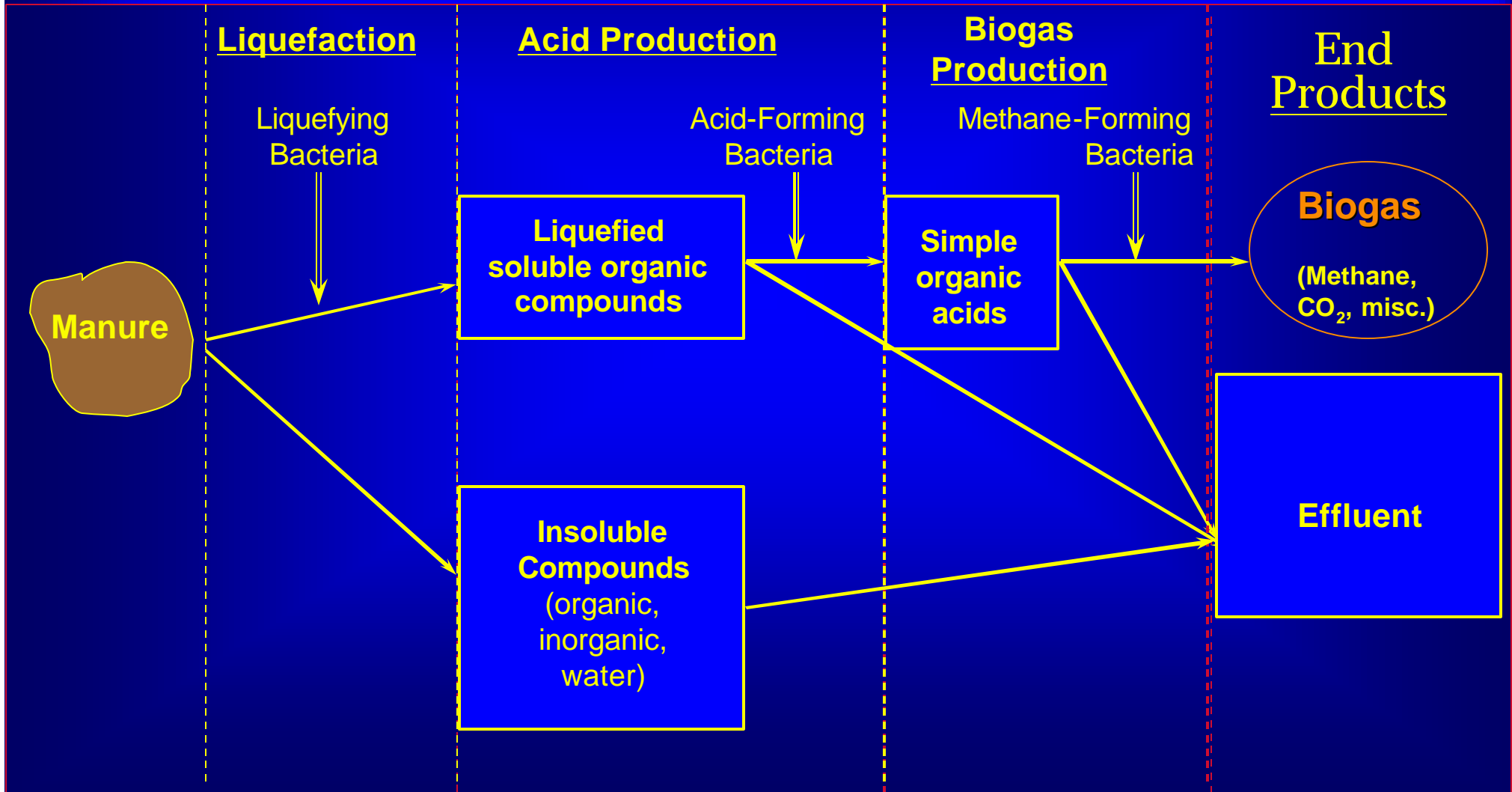
- Hundreds of farm-based digesters operating in Europe plus several centralized AD systems
- Danish systems co-digest manure, organic industrial wastes and municipal solid waste
- Large numbers of family-sized, low technology digesters in developing world provide biogas for cooking and lighting
- Renewed interest in U.S.

Environmental Benefits

- **Reduces odor from land application**
- **Protects water resources**
- **Reduces pathogens**
- **Weed seed reduction**
- **Fly control after digestion**
- **Greenhouse gas reduction**



Anaerobic Digestion Process





Temperature

- Two distinct temperature ranges in which anaerobic bacteria produce significant amounts of methane gas –
 - mesophilic range (90-110F)
 - thermophilic range (120-140F).

Gas Production Potential - Manure

Animal Type	Daily BioGas Production Per Mature Animal*
Dairy cow	50-80 ft³ (~40,000 Btu)
Hog	4-6 ft³ (~3000 Btu)

Source: EPA 2005

* Optimistic for most farms

BioGas cleanup

- Corrosion can be a problem in contact with metal. May need treatment to remove hydrogen sulfide and water vapor from gas
- Condenser can remove water vapor
- Molecular sieve can remove carbon dioxide in future?



Types of Digesters

- **Covered Lagoon**
- **Complete Mix**
- **Plug Flow**
- **Fixed Media**

Typical Digesters in Midwest

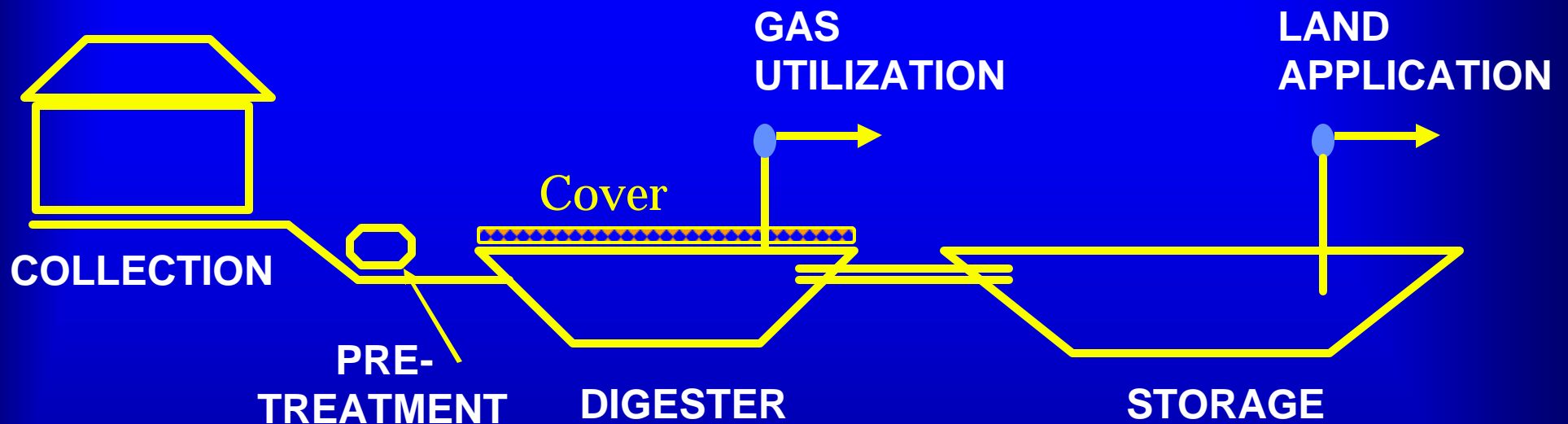
	Covered Lagoon	Complete Mix	Plug Flow
Level of Technology	Low	Medium/High	Medium
Digestion Vessel	Deep lagoon	Round, square in/above ground	Rectangular in ground
Supplemental Heat	No	Yes	Yes

Typical Digesters, cont.

	Covered Lagoon	Complete Mix	Plug Flow
Solids Concentration	0.5-2%	3-8%	6-11%
HRT ¹ (days)	45+	15+	15+
Optimum Location	Warm climates	All climates	All climates

¹ HRT = Hydraulic Retention Time

Covered Lagoon



Lagoon typically $\frac{1}{2}$ -2% solids

Source: EPA 2005

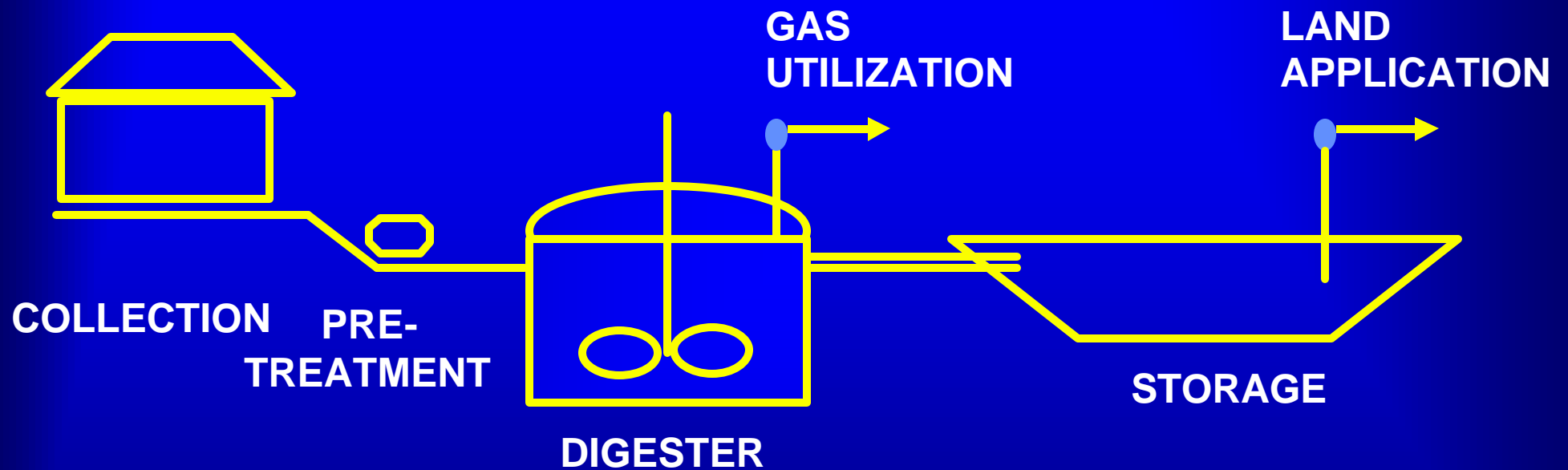


Covered Lagoon

- Advantages:
 - Relatively inexpensive to build
 - Adaptable to hydraulic flush removal of manure
 - Simple construction and management
- Limitations:
 - Limited to warm weather areas since digestion depends on temperature
 - Manure not completely digested, so some odor released when land applied

Source: David Downing, Iowa Department of Natural Resources, 2002

Complete Mix Digester



Slurry typically 3-8% solids

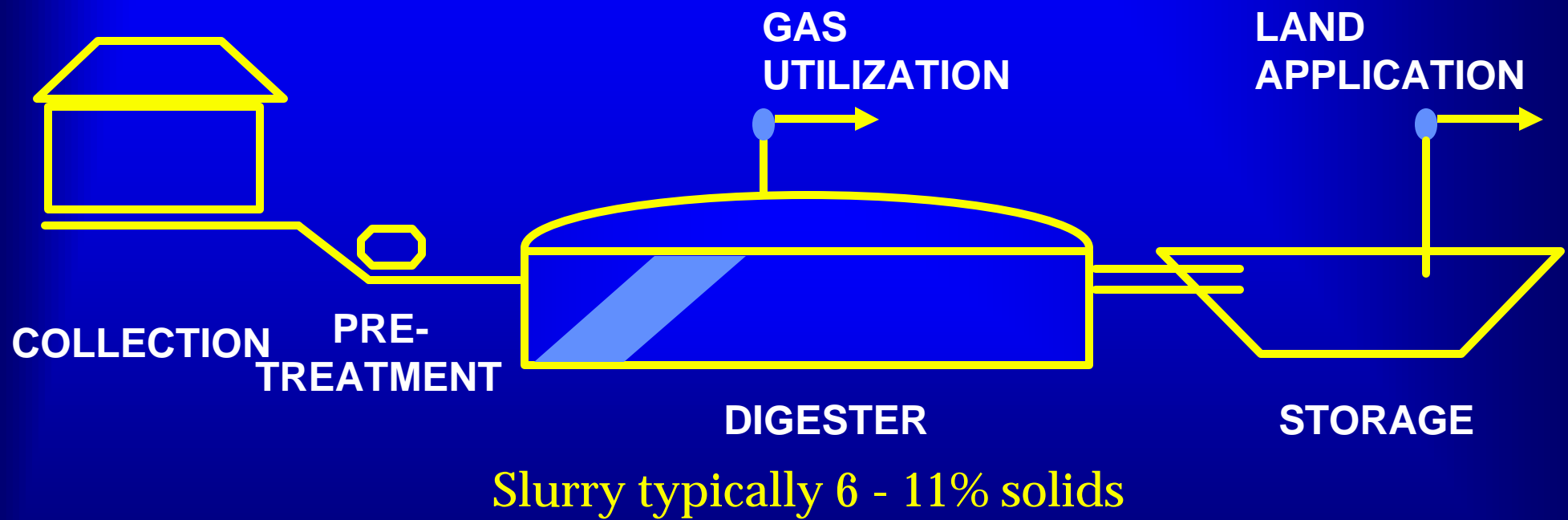
Source: EPA 2005

Complete Mix System

- Advantages:
 - Mechanical mixers prevent crust and keeps solids from collecting on the bottom of the digester tank, delaying cleaning
- Limitations:
 - Requires more maintenance
 - Requires more energy to operate

Source: David Downing, Iowa Department of Natural Resources, 2002

Plug Flow Digester



Source: EPA 2005

Plug Flow Digester

- Advantages:
 - Medium cost range
 - Simpler design that “complete mix”
 - Less labor/management intensive to operate
- Limitations:
 - Most compatible with daily scrape manure systems
 - Requires pre-mix tank ahead of digester

Source: David Downing, Iowa Department of Natural Resources, 2002

Fixed-film Anaerobic Filter

- Upflow digester with porous media
- Bacteria grows on media and feeds on organics passing by
- Wastewater passes thru in 4-6 days but slow-growing bacteria remain in digester – much smaller digester
- Low Food:Mass ratio makes system stable

Carbon Credit Programs

- Greenhouse gases - Methane is over 20 times more damaging than carbon dioxide
- Agricultural carbon credits traded on exchange to industries who have trouble meeting environmental requirements
- Several producers already enrolled in carbon credit programs worth millions of dollars

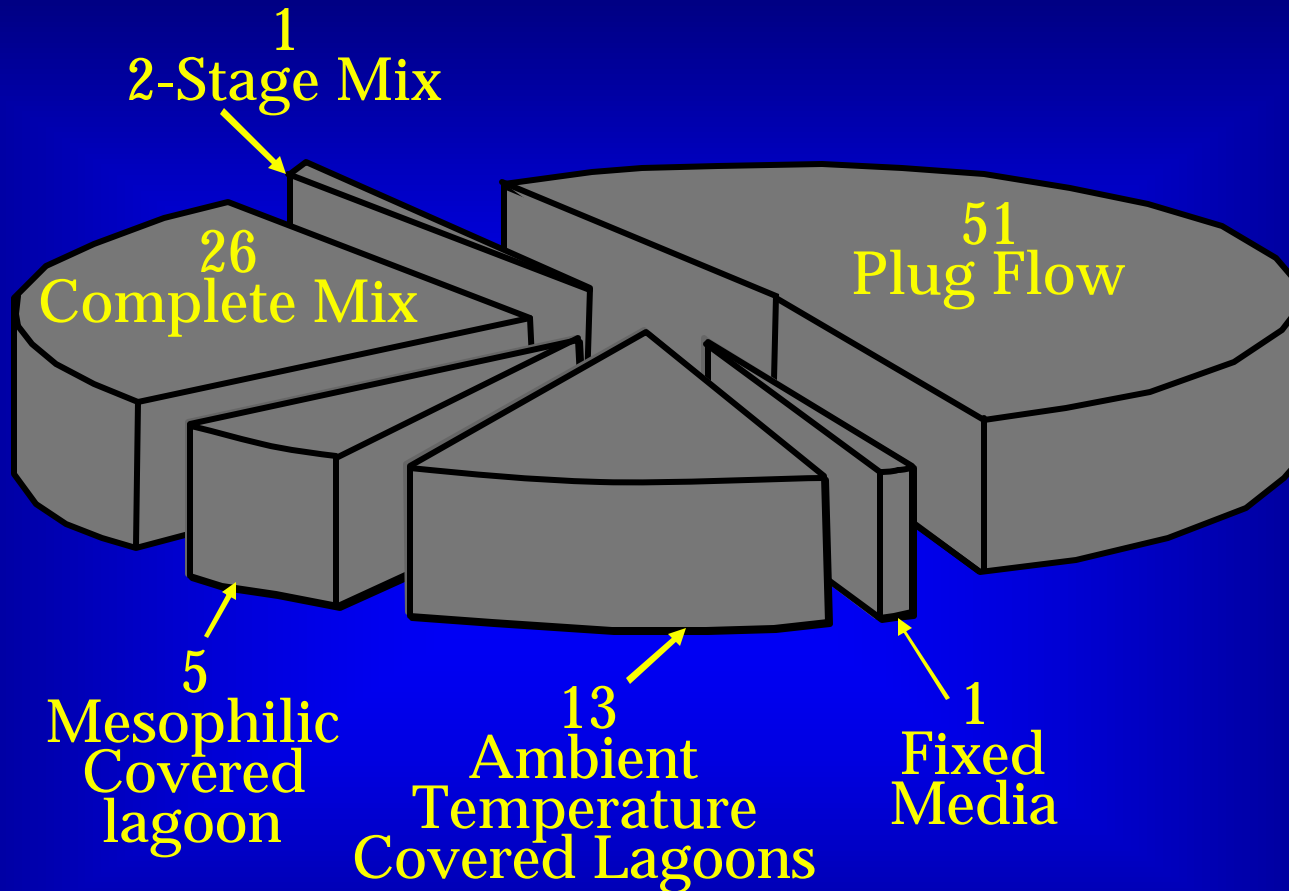
(www.envcc.com)

Source: EPA 2005

Safety Considerations

- Methane is extremely explosive when mixed with air at the proportions of 6-15 percent methane
- Digester gas is heavier than air and settles to the ground, displacing oxygen
- If hydrogen sulfide is present, digester gas can be a deadly poison

Source: EPA 2005



Source: EPA 2005

Agricultural Digesters in US

Methane Energy Recovery Incentives

AgSTAR

- Mission is to show dairy and pork producers "how to manage manure profitably while protecting the environment.
- For potential funding information, contact
AgSTAR: 1-800-95-AgSTAR

<http://www.epa.gov/outreach/agstar/iondex.htm>